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Work by Prof. Smith and his collaborators is summarized here.

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Distortion-Free X-Ray Mask Technology

Quarterly Technical Report
for the period
June 11, 1990 to September 11, 1990

by
.esearch Laboratory of Electronics
Massachusetts Institute of Technology
Cambridge, MA 02139

Principal Investigator

Prof. Henry I. Smith
Dep' of Electrical Engineering and Computer Science
Massachusetts Institute of Technology

September 11, 1990

Objective:

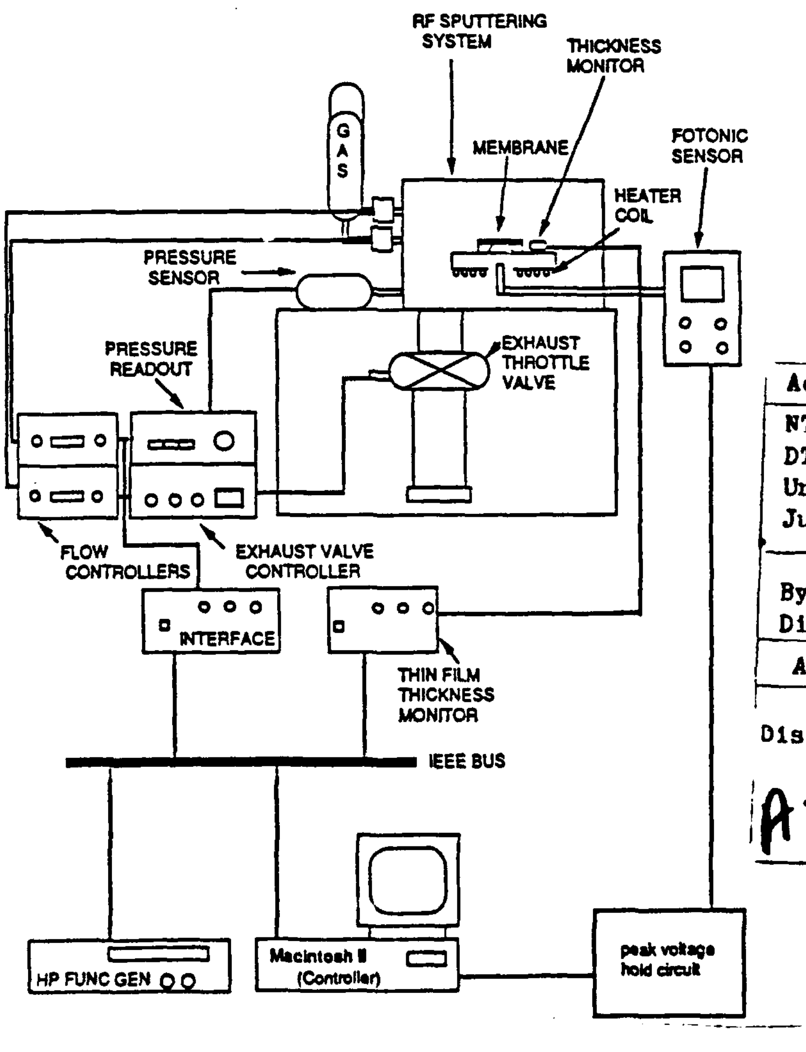
The objective of this research project is to develop a closed-loop, feedback-controlled, robust system for reliably achieving zero stress in tungsten (W) films sputtered onto various x-ray mask membranes, and to transfer the technology to the National X-ray mask shop. Our system for controlling stress in sputtered W films is based on the measurement of resonant frequency. Since resonant frequency depends on both the thickness and the stress of the W films, if the thickness is known, the stress is easily calculated from

$$\nu_{res} = \left[\frac{B+\sigma_w t_w}{c+dt_w}\right]^{1/2}$$

where A,B and C are constants, known in advance, σ_w is the tungsten stress and t_w is the W thickness.

Progress:

We have set up an rf sputtering system, a fixture for driving the membrane into oscillation, and optical means of detecting the membrane motion, as shown in Fig. 1.



During the past 3 months we have passed the 3 milestones for this period, as described in the next 3 paragraphs:

1) We built and tested a peak detector and signal amplifier for the membrane displacement optical detector. The MacII control computer was equipped with a MacAdiosII 12-bit A/D converter with an input range of +10V and 5mV per LSB resolution. The photonic sensor's vibration output (~100mV peak output at resonance) was far too small to be directly measured. A small peak-hold circuit was built to amplify the signal and filter out the noise. A simple fourth-order Butterworth filter with a cut off frequency of 1kHz was used to filter out the 60Hz power line noise and the three-phase 180Hz noise. The capacitive coupling at the input stage provides further filtering below 1kHz.

2) We have set up an algorithm to determine and track membrane resonant frequency. The program which implements the tracking of resonant frequency of the membrane is written in C. This program executes one frequency sweep at a time and displays a plot of the amplitude versus the excitation frequency. At the same time it searches for the maximum vibration amplitude over this interval and the corresponding frequency. The user can specify the parameters such as sweeping frequency range, sweep time, number of data points, driving amplitude and DC offset, and the types of sweep (one sweep and two sweep). The last option is necessary because the Q of the membrane is so high that the actual amplitude peak occurred later than the resonant frequency. By first sweeping upwards in the frequency and then backwards, and averaging the maximum amplitude frequencies of both sweeps, we can determine the resonant frequency with very high accuracy and precision.

3) The Mac II computer, can now acquire data on resonant frequency, film thickness (from the film thickness monitor), pressure, gas flow rate, throttle valve position, and platform temperature. A MKS-246 mass flow controller for precise setting of Ar gas flow rate, a MKS-390HA pressure sensor for accurate pressure read-out, and a MKS-252A throttle valve are all tied into an MKS-288 IEEE interface unit which allows the MacII computer to set and monitor the sputtering chamber pressure. In addition a Sycon thin film thickness monitor for precise tungsten thickness measurement, and a HP 3325B function generator for precise membrane excitation are all tied to the MacII through an IEEE-488 interface unit. All the controlling of the instrument and the data acquisition are done with a program written in C. The instrument setting and the measured resonant frequency are all displayed on the monitor together with the frequency sweep data.

A number of test runs have been carried out using the partially configured in-situ monitoring system. That is, we can deposit W and control W stress on nitride membranes to within 1×10^8 dynes/cm^2, provided a human operator carries out those feedback functions we have not yet automated.

We have supplied to NRL 4 wafers coated with zero-stress W, for use as substrates in e-beam lithography experiments.

We have completed a number of experiments on reactive ion etching of W. Specifically, using the gas combination $CCl_2F_2/CHF_3/O_2$, we have etched 0.5 μm and 0.25 μm lines and spaces in 0.4 μm thick W, using novolak resist as a mask.

Items beyond Statement of Work:

In addition to the items listed in our Statement of Work, we have gone beyond this and studied other aspects of the x-ray mask problem that are of interest to the National X-ray Program, such as testing the strength and radiation hardness of various mask membranes. At present it appears that Si-rich nitride is by far the best candidate for an x-ray mask. Preliminary tests under heavy x-ray doses at the Univ. of Wisconsin synchrotron indicate that radiation damage to our nitride is negligible. We plan to set up at MIT our own LPCVD Si-rich nitride system.

Summary:

In summary, we are highly pleased with our progress to date on in-situ stress control and believe a robust system will be completed on schedule.

NAVAL RESEARCH LABORATORY

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